OPTIMIZATION OF REFRACTORY LINING USED IN BLAST FURNACE

A thesis Submitted in partial fulfillment of the requirements for the award of the degree of

Master of Technology

In

Mechanical Engineering
(Thermal Engineering)

By

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National Institute of Technology Rourkela
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Under the guidance of
Prof. S. K. Sahoo

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CERTIFICATE

This is to certify that the thesis entitled, "**OPTIMIZATION OF REFRACTORY LINING USED IN BLAST FURNACE** " submitted by **Mr. PRAMOD KUMAR BHAGAT** in partial fulfillment of the requirements for the award of Master of Technology Degree in Mechanical Engineering with specialization in **Thermal Engineering** at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter summarized in the thesis has not been submitted to any other University/Institute for the award of any degree or diploma.

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ABSTRACT

The refractory lining with stave 3D model in blast furnace is analyzed and design by using the ANSYS software. This model is used for analysis the effect of refractory lining thickness with different cooling rate. The cooling of refractory is the essential feature for the blast furnace campaign life. The cooling of refractory lining can be done by stave cooler. It is cooling device that maintain the innermost profile of blast furnace. The refractory materials which are used in this experiment are aluminum oxide and silicon oxide with different stave materials is copper, aluminum and cast iron. The experimental data are collected from Rourkela steel plant for developing a 3D model of refractory lining of stave cooling. The refractory lining thickness of the blast furnace is in use as 650 mm. Stave material used such as aluminium and copper. Water is used as a cooling agent.

Keywords: Refractory Lining, Stave Coolers, Heat Transfer.

ACKNOWLEDGEMENT

I would like to thank and express my deep sense of gratitude towards my supervisor **Prof. S. K. Sahoo** for his broad backing all through this task work. I am greatly obligated to him for giving me the chance to work with him and for his belief in me during the hard time throughout this work. His significant recommendations and consistent consolation helped me to finish the project work effectively. Working under him has in reality been a great experience and motivation for me.

PRAMOD KUMAR BHAGAT

213ME3425

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NOMENCLATURE

υ = Kinematic viscosity, (m^2/s)

ρ = Density, (kg/m^2)

μ = Dynamic viscosity, (Ns/m^2)

D = Diameter, (m)

Re = Reynolds number

DT = Temperature difference (K)

Q = Heat extracted, (W)

$q_{,,}$ = Heat flux, (W/m^2)

m = rate of Mass flow, (Kg/s)

A= stave area, m2

L = stave length, m

C_p = Specific heat, J/kgK

K = Thermal Conductivity, (W/mK)

CHAPTER 1

1.1 INTRODUCTION

1.1 Introduction

For defining the blast furnace campaign life, refractory lining play an important factor. The main significant feature of blast furnace campaign life is cooling of refractory lining. The cooling of refractory lining can be done by stave cooler. It is cooling device that maintain the innermost profile of blast furnace. It is made up of cast iron, copper and aluminium. The campaign life of blast furnace mostly depends on upon the various features that are lesser absorptivity due to high coal infusion, more liquid speed affecting more erosion and more efficiency primary to more loads. A long furnace campaign is certain by point by point investigations and studies, utilization of present day outline and materials, close and watchful assessments, utilization of most recent development procedures, site supervision, obstinate dry-out/warm-up/ appointing. Essential important points of refractories are long lifetimes for most amazing furnace, savvy, precisely selected materials for every furnace zone and quick installation.

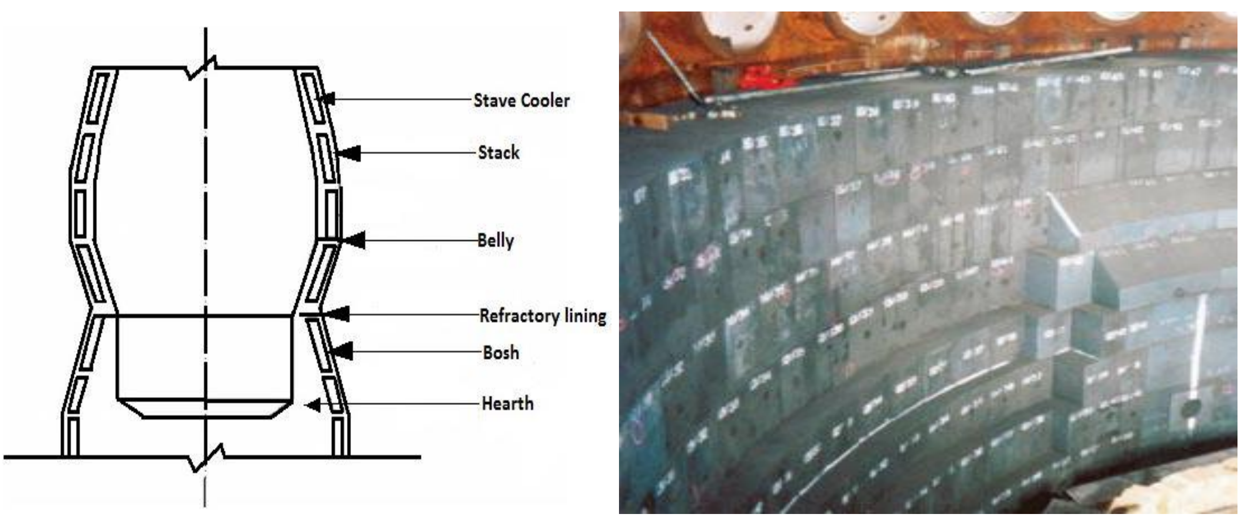


Figure 1 arrangement of stave cooler of blast furnace and refractory of blast furnace [21].

1.1.1 Types of refractories

There are two types of refractories are as follows:

1.1.1 Clay refractories- the main kinds of clay refractories are ladle, insulating, high alumina and fire clay.

1.1.2 Non-clay refractories- the main kinds of non-clay refractories are iron, silicon carbide, silica, mullite, fused cast and extra-high alumina.

Figure 2 Refractory [21]

Other types of refractories are:

1.1.3 Shaped refractories- fixed shaped.

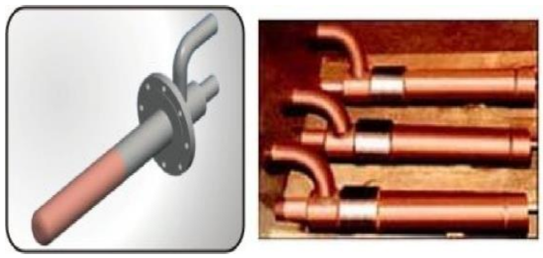
1.1.4 Unshaped refractories- definite form (monolithic refractories).

1.1.5 Acid refractories- fire clay bricks and silica.

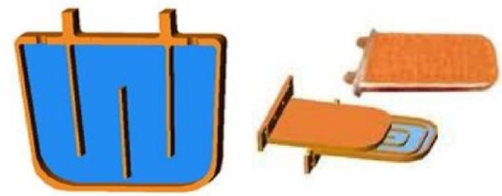
1.1.6 Basic refractories- dolomite, alumina, magnesia, chromium.

1.1.7 Neutral refractories- zirconia and alumino silicates.

1.1.2 Different types of cooler



a. cigar cooler



b. plate cooler

c. stave **cooler**

Figure 3 Different types of coolers

1.1.3 Refractories material

1. Aluminium oxide (Al_2O_3)

2. Silicon oxide (SiO_2)

3. Mullite

4. Magnesia (MgO)

5. Dolomite ($CaO*MgO$)

6. Chromite

Figure 4 refractory materials

1.1.4 Stave materials

- Cast iron
- copper
- aluminium

1.1.5. Refractory properties

- Elasticity is low.
- Thermal extension is low
- Penetrability is low
- Resistance of alkali
- Thermal conductivity is high

1.1.6 Advantages of Refractory

The common necessities of refractories material can be follows as:

- Capacity to with stand high temperatures and trap thermal inside of restricted range such as furnace.
- Capacity to with stand activity of slag disintegration, hot gasses and liquid metal and so on.
- Capacity to with stand load at administration circumstances.
- Capacity to oppose of material destruction through that it comes from into interaction.
- Capacity to keep up adequate dimensional security at high temperatures and in the wake of/during repeated thermal cycling.
- Its capacity to save heat.

1.1.7 APPLICATIONS OF REFRACTORY

These are Steel and iron industry, Hearth, Sidewalls, Burner Ports and Slag Door, Roof, Nozzles, Copper Industry, Aluminum Industry, Cement Industry, Glass Industry.

a. **b.**

Figure 5 a. and b. refractories chamber[22]

CHAPTER 2

1.2 LITERATURE REVIEW

LITERATURE REVIEW

YUNG-CHANG KO et al [1]. Has studied about thermal behavior analysis in tap-hole area by utilizing a CFD fluent. An accuracy of model is confirmed by contrasting the simulated temperature distribution and site practical data. The thermal characteristic of brick, cast able and mud-center was discovered. The important influence on tap-gap territory temperature distribution is coefficient of convection heat transfer. By conforming thermal characteristic of material, the pattern of thermal behavior calculated by the created model of hearth. It is useful in ability the temperature distribution of the tap-opening range, which can be a reference to change the cooling operation.

ALLAN MACRAE et al. [2]. Studied about a new method of lining a blast furnace bosh and stack. The essential to build the campaign life of furnace, another technique for furnace lining has been produced. Issues with existing lining system or operational changes have created furnace campaign to be cut short because of disappointments in the bosh or stack. This new system is intended to build the life of the furnace by looking after a more uniform temperature and upgrading the quality qualities of the segments. A system is combination of stave and a two-fold locking refractory system is particularly intended to overcome bending, water spills and surface wear issues seen in numerous furnaces all through the industry. The system decreases the measure of heat misfortune through the vessel wall, expands bosh and stacks lining life and can be introduced using existing furnace pumping/cooling system and shell opening. The innovation will be introduced demonstrating the novel strategies used to overcome current issues creating decreased furnace campaign life.

Anil Kumar et al [3]. The blast furnace cooling are established and studied by 3D thermal stress and heat transfer. The component technique programming ANSYS utilize thermal cooling stave in thermal stress is figured. In the computational study the radiation heat transferred from strong material like flux, metal and coke to cooling stave is disregarded. There are two unique kinds of materials of lining are in use that are high silicon carbide brick and high. The gas temperature utilized the stave with skull and the characteristic loads utilized the material of lining. In demonstrating and additionally in investigation, the limit circumstances and distinctive uncertainties are taken. the sort of data is taken in heat transfer of cooling stave. These effects demonstrate the thermal stress and hot face temperature are most negligible in high alumina brick and most elevated in silicon carbide brick. The silicon carbide brick is enhanced, therefore it can different circumstances that influence the furnace campaign life and cooling stave. Therefore the silicon carbide brick suitable furnace lining for the stave.

Lijun Wu et al [4] By numerical calculation as well as analysis, the model of calculation of convection coefficient among hot surface of stave body as well as flow of furnace gas, in-laid brick and flow of gas was secured. This is the purpose so the heat transfer coefficient among in-laid brick and flow of gas are more than that in the middle of stave body and gas was studied while a high temperature of gas. Although changed the mathematical solving of heat transfer of stave model, the assessments just to since a category of determination of coefficient of heat transfer. The level of heat transfer numerical calculated when the two coefficient of heat transfer separation will expand.

Lu zuan et al. [5] An insightful reproduction method is produced when the furnace stave thermal position. The computerized reasoning method and heat transfer of scientific model utilized the constructed model of clever recreation. The simulated model stave in cast steel of furnace is in light of revision variable of parameters acquired via preparing the specimens of test information of the cooling stave. Reproducing right now standing stave circumstance that is just a observing fact on stave of furnace and speed and temperature of cooling water are troublesome towards constant is identified, the model experimental patterned is finished. The consequences demonstrate which the information of model of careful reproduction is about steady with that of investigation. The more exactness model is on-line anticipate the thermal position of stave in furnace.

Maria Swartling et al. [6] The studied have concentrated to flow of heat generation at hearth of furnace is decided. The some piece is presented to more temperatures of furnace. The end goals to build the battle length of the covering enhanced information of heat flow are vital. By heat transfer showing it has been mulled over both numerically and tentatively. Estimations of external apparent temperatures in the inferior a piece of generation blast furnace were done. For the exploratory study, relationships were created among coating temperatures and external surface temperatures. The relationships were utilized a limit circumstances as part of a scientific model, in which the temperature contours in the hearth covering are figured. The forecasts demonstrate which the angle among the wall and the base is maximum delicate piece of the furnace hearth. Besides, these expectations demonstrate which no concentrated on amount of the covering taken an internal temperature anywhere iron melt can be in interaction with furnace lining.

G. X. WAN et al. [7] Three-dimensional in the lower stack modeling of region of the wail blast heat furnace. This paper describes a numerical model, together with its answer strategy grew by the limited component system, to reenact the three-dimensional heat move in mass of inferior stack section of furnace and the wall comprising of water-cooling segments and criss-crossing refractories. These methodology are accepted by great understanding between measured radial temperature and computed conveyances, therefore this is study the heat transfer transform underneath different working circumstances and water-cooling of furnace. The outcomes demonstrate which the transfer of heat and subsequently the wear development in blast furnace wall can be precise by legitimately modifying working circumstances of furnace.

Jan TORRKULLA et al. [8] The model for skull shapes heart of furnace and assessment of disintegration is introduced. A model of wall lining and hearth bottom, gauge of thermocouple is estimate. The greatest extreme disintegration of lining practiced in the course of in progress thickness of the skull solid and campaign. A model is delineated going on procedure information beginning double finish furnace. Reciprocal estimations and counts are utilized to check the outcomes. In view of the discoveries, assumptions are strained almost the inner condition of the hearth of the furnace. At long last, a few proposals on the most proficient method to mechanism the condition of the hearth of the furnace are given.

Kuncan ZHENG et al. [9]. The important variables influencing the furnace campaign life is erosion of lining. The primary approach to learning the furnace lining erosion is mathematical recreation in the CFD enhancements and PC improvements. The latest exploration after effects furnace lining consumption is controlled and numerical reproduction remained inspected. The certain critical issue of existent was examined, and a few suggests for upcoming improvement were given,

S.B. Kuang et al. [10] Numerical study of hot charge operation in iron making blast furnace. The important natural and energy an advantage to the process of furnace is the iron-making constituents and hot coke charge. These are the information data about the numerical impacts of process of hot charge of execution and flow on furnace. These papers show a multiphase flow numerical study, mass and thermal move by a model of procedure in a furnace. Different applications confirmed the suitability in predicting model execution of the furnace. At dissimilar temperatures the impacts process of charge of hot study is used. The outcomes stay investigated in point of interest through appreciation to blast furnace presentation and flow. This is demonstrated which contrasted with routine process, operation of hot charge be prompt expanded profitability, CO2 outflow and diminished coke rate, and at the similar period, temperature of top gas and expanded gas weight. These impacts change with charge of hot temperature.

Dong Fu et al. [11] The iron making furnace is a counter-current chemical reactor which incorporates the ascending gas flow and the counter-current descending permeable bed. CFD models have created to recreate the multiphase responding flow in furnace shaft. The gas flow elements, load development, synthetic responses, thermal and mass transfer between the gas stage and weight stage are incorporated in the CFD model. The furnace weight comprises of option layers of iron metal and coke. A novel strategy is proposed to productively show the impacts of option weight layer structure on gas stream, heat transfer, mass transfer and compound responses. Different responses and heat transfer qualities are demanded distinction sorts of layer. The layered CFD model precisely predicts the Cohesive Zone (CZ) shape where the liquefying of strong weight occurring. The shape and area of the CZ are controlled by an iterative system taking into account the metal temperature dispersion. The hypothetical arrangement and the procedure of the CFD model are introduced and the model is connected to recreate industry furnace. The proposed technique can be connected to research the furnace shaft methodology and other moving bed system with occasional weight structure configuration.

CHENG Su-sen et al. [12] An observing strategy that has been intended stimulatingly wall by copper stave for furnace fabricated. Combining a technique for "reverse issue" and the idea "non-backwards issue", the observing system for furnace wall with copper stave has been acknowledged which is utilized to compute connected the accumulation temperature and thickness of copper stave in hot surface in the wake of the acquiring the estimations of the copper stave of the thermocouples. The growth formal got happening the real study have demonstrated which the after effect of the project remains right. The checking project demonstrates which the accumulation is effortlessly vary after the growth film is greatly thin and thick, along these lines steady then the impact furnace of smooth operation is prevented. In keeping up proper accumulation thickness, both long campaign and high profitability of the furnace can be attained to; moreover, improve the operation of furnace and boost its creation. Give or take 30-50 mm in thickness of gradual addition layer is kept up on the mass of Shrugging furnace, which can meet the necessity for acquiring both long campaign and high productivity.

XIE Ning-qiang et al. [13] The impact of temperature of variety going on stave of cooling is study. Displacement, stress and temperature distribution of cooling stave was examined individually after gas temperature interior-furnace. The outcomes demonstrate which the temperature ground going on cold side remains beneath cooling channels is control and scarcely variations after gas temperature increments. The temperature angle and variation rate with time close hot edges is more prominent. The side of stave is determined to cool side also center region concerning altered jolts and hot side of pin moves. A displacement about altered smaller pin however bigger proceeding the edge and greatest is situated of top surface on hot part.

S.j. Zhang et al. [14]. The solids utilization and coke and layer-charging of iron-bearing is study. Because of a numerical model as of created for gas–solid two-stage flow based the coke ignition in the course. It contains the metal as well as coke shapes, profitability, and solids volume misfortune because of ignition, lessening, emergency and shrinkage by means of decided since regular working circumstances. The outcomes exhibit which the mass misfortune emphatically influences the flow of solid design and dead man profile in furnace. Specifically, expanding solids utilization amount determination build a strong velocity and the extent of deadman is diminish.

Y. Kaymak et al. [15] The geometrical configuration and material decision for a hard-headed covering obliges a complete comprehension of its thermo-mechanical conduct. Outline builds unmistakably need an instrument for quick and effective reckoning of thermo-mechanical condition of obstinate linings under different conditions. The standard simulation models and their solution endure as the linings are made out of numerous refractory blocks in contact. Accordingly, a simplified way to deal with the contact in thermo-mechanical study of refractory linings and its usage are presented. This system gives a much quicker model arrangement and arrangement than the conventional contact models with an excellent precision. The acquainted method is suitable with a wide scope of mechanical refractory linings, for example, blast furnace, converters, ladles, etc.

Akash Shrivastava et al. [16] A systemic survey and study lining material of cooling stave of furnace utilized as a part of the metallurgical commercial enterprises in view of heat transfer study. the paper describe a model that determination be demonstrated also actualized utilizing demonstrating programming. The model will be more remain used meant for the study of the conduct of coating constituents through heat transfer at distinctive loads study through limited component system programming is ANSYS. There are two unique sorts of bricks such as high alumina bricks and silicon carbide brick that will be occupied of the furnace cooling stave for the lining material and additionally considered the two distinct sorts of skull, in that the principal is taking immaterial thickness and other is consuming definite thickness along these lines with two skulls.

S. J. GD ULA et al. [17]. A strategy for deciding the temperature distribution in steady state in furnace hearth of the furnace and base is known. Different cooling and coating system remained measured. A strategy for arrangements join is connected. It is obtained a genuinely great assention of find and processed results. A scientific furnace hearth and model of heat transfer base and some furnace cooling system was produced. The model was taking into account a unique technique called arrangements coupling technique. A PC project was produced, skilled to arrangement for all intents and purposes with any current furnace cooling system. Another system can be incorporated in this project with no huge extra programming exertion. A genuinely decent understanding of figured and measured results was acquired.

Cheng-Peng Yeh. Et al. [18]. A conjugate heat transfer model was created for relentless state procedure together with heat transfer of sensor and stave bar from the gas temperature in radiation transmission and thermal conduction intimate the furnace and cooling pipe of convection heat transfer. A simulation concentrate particularly the thickness of slag layer or material and thickness of cooling stave geometric on impacts of gas temperature distance across the sensor bar on impacts of gas temperature. The outcomes demonstrate which the slag shell and refractory lining give huge assurance to the stave. The copper sensor bar would utilize to find lingering covering of stave body thickness. To measured sensible stave thickness, few key elements, for example, the material and measurement of sensor bar, was analyzed. These outcomes can help as vital position data for campaign life and operation of furnace.

Zhou Weiguo et al. [19] They developed 3D numerical model of thermal momentum field and different temperature of cooling stave in cast steel have displayed. Sorts of data improvement of cooling stave cast steel are proposed in furnace taking into account the examination of heat transfer. Decreasing the temperature of water could be inefficient. The temperature of water is picked by nearby conditions. The bricks of silicon carbide as well as silicon nitrogen bond are the best decision used for materials of furnace lining.

Cheng Hui'er et al. [20]. The component system programming ANSYS are utilized for calculated the 3D thermal stress and heat transfer of a cooling stave. The consequence show the maximum temperature rise also stave hot surface stave of thermal stress is not greater once cooling curved tube supplanted the cooling funnel. Due to reduction in cross-sectional range for circular tube cooling, cooling stave thickness is lessened and saved the cooling water flow. Thus it reduced the expense of iron-production.

2.1 Summary

Subsequent to experiencing pertinent diaries it is found that distinctive material are utilized as a part of refractory material and broke down the stave cooler utilizing cooling medium water, however even not heated over about thickness of refractory lining likewise not utilized nitrogen as a part of the spot of water for cooling the refractory lining.

CHAPTER 3

1.3 EXPERIMENTAL AND NUMERICAL ANALYSIS

1.3.1 Experimental analysis

The 3D geometry & mathematical study of refractory lining with stave body utilized in furnace of RSP. For test information a stave body that is liable to the greatest heat stacking the furnace. With the help of ansys software an analytical model have been developed taking a definite measurement from RSP data. To build up geometry we plan dimensionally in distinguishable coil cooling with help of effort seat. The cooling of coil created is great forced in quadrilateral strongbox dimensionally in distinguishable to the lay open to experimental stave body. The geometry created is precisely dimensionally in distinguishable to genuine stave body utilized as a part of RSP .

This model created through support of the effort table remains fare toward study of fluent the heat transfer conduct of real heat stack versus stave body. We collect the basic information from experimental arrangement of the similar recognized stave body. The exploratory data comprises of two quantities of temperature calculating gadgets built-in to the channel and outlet of stave body. Volume stream meter is introduced in inlet contour to gauge volume stream interior to the stave body. A mass gage introduced in liquid stream link to demonstrate liquid weight in stave body.

Since test set up we ascertain genuine heat mass in subject stave body table specified underneath. We saw temperature of outlet and channel as well as requirement of temperature here off in stave body (DT) in specific measurements of flow of fluid. At point once the similar heat load figured since exploratory system is put in logical ideal. The temperature distinction (dT) discovered as in genuine set up. The experimental is proceeded used for distinctive sorts of liquid in setup. We measured the test arrangement quality utilizing water as cooling intermediate and after that supplant by nitrogen. The quality got for all intents and purposes discovered to be precisely in distinguishable as in the product model. The test setup as demonstrated in the Figure 6.

Figure 6 Experimental setup

3.1.1 Experimental Data

These are test information taken from RSP utilizing water as cooling operatives specified beneath in Table 1.

Table 1 experimental data from RSP

Stave cooler	Inlet temp(T_1) in °C	Outlet temp(T_2) in °C	Difference ($T=T_2-T_1$)	Water collected (litres)	Time in second
1	27.4	32.8	5.4	30	54
2	27.4	30.8	3.4	30	64
3	24.4	30.8	6.4	30	60
4	24.4	35.6	11.2	30	48
5	24.4	33.2	8.8	30	46
6	24.4	31.4	7	30	43
7	24.4	32.8	8.4	30	57
8	24.4	35.4	11	30	44
9	24.4	34	9.6	30	47
10	24.4	32.6	8.2	30	43
11	24.4	31.6	7.2	30	52
12	24.4	30.6	6.2	30	54
13	24.4	32.8	8.4	30	48
14	24.4	37.6	13.2	30	53
15	24.4	30.2	5.8	30	48
16	22.4	30.4	8	30	51
17	22.4	30.4	8	30	48
18	22.4	28.4	6	30	53
19	22.4	28.2	5.8	30	58

3.2 NUMERICAL ANALYSIS

3.2.1*Computational investigation*

In the benefit of program design ANSYS the geometry of refractory lining through stave body cooling is finished. By this product work table is uniquely utilized for model & cross section of geometry. The few stages clarify underneath:

Modeling of Geometry: A 3D stave body cooling through refractory lining taking unique measurement of 850mm width, 898mm height and 1640 mm length is drawn by the design of outline secluded. In the Figure7 demonstrated that most importantly I must draw stave coil taking measurement of the bending radius of the coil is 80mm , 8421mm total length and 33mm distance across. After finishing of the stave coil I must draw the stave body 200mm width, 898mm height and 1640mm length as indicated. In the Figure 9 and Figure 10 individually indicated further it remained expelled by z-direction in 650mm for expansion of lining material.

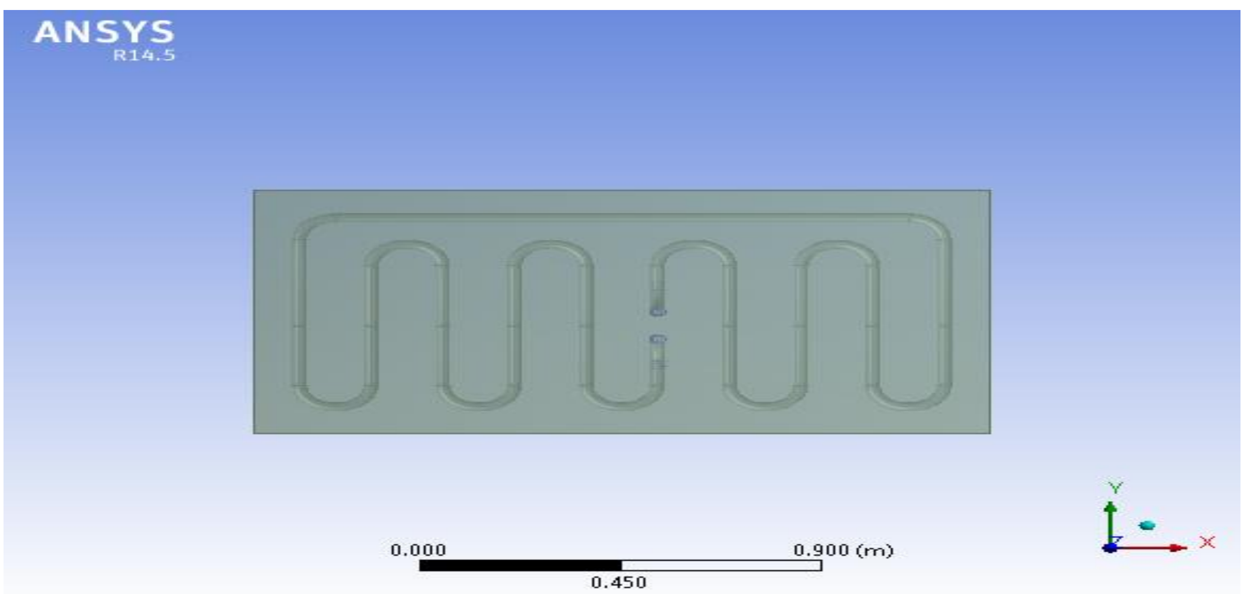


Fig.7. in x-y coordinates Stave coil

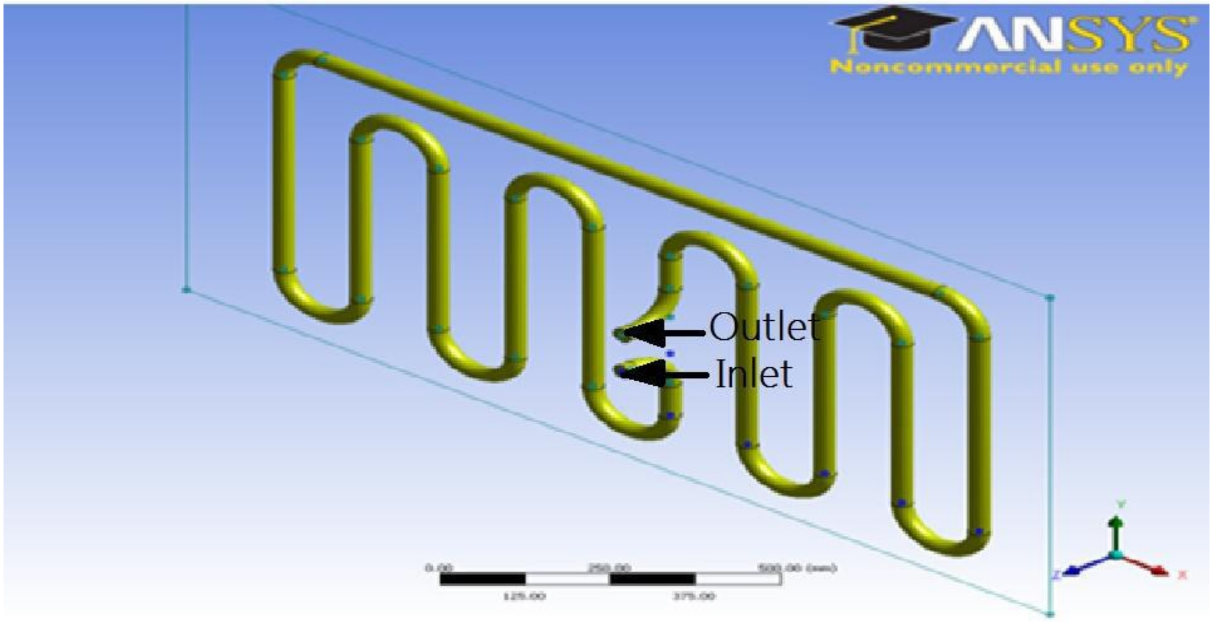


Figure 7 stave coil Isometric view

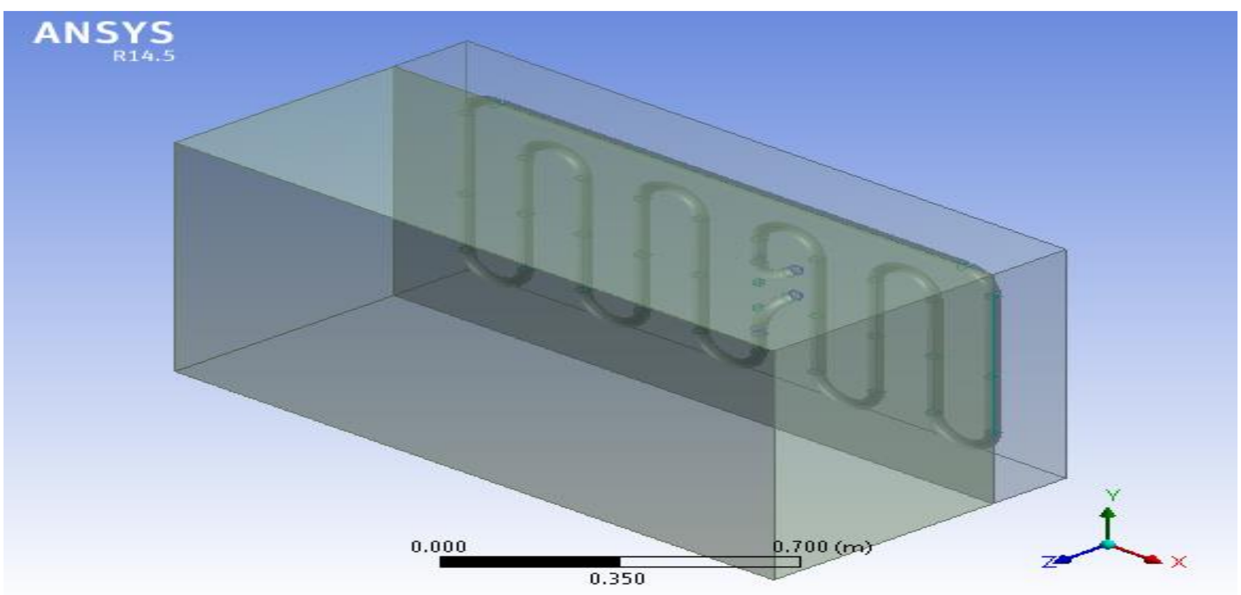


Figure 8 stave cooler with refractory lining Back side view.

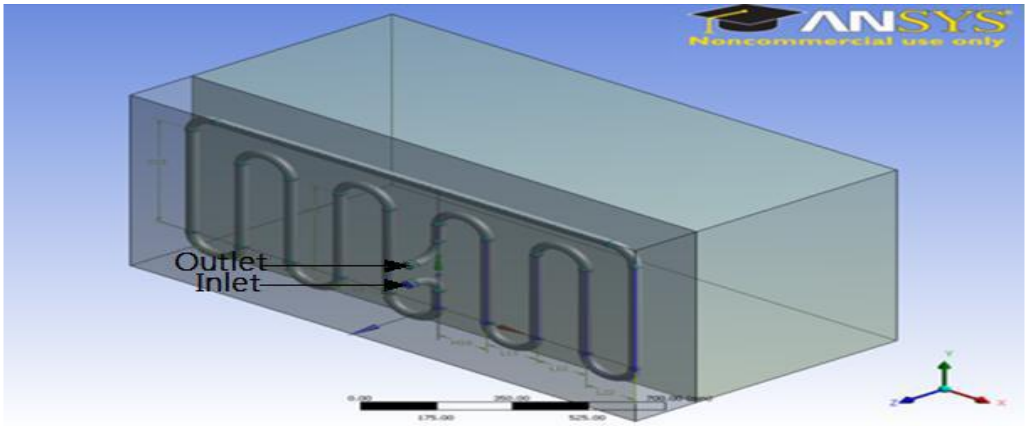


Figure 9 refractory lining with stave cooler Isometric view

Mesh formation- in ansys work table Subsequently diagram the model of stave cooler refractory lining it is traded to work and afterward choice contact area (liquid is contact body and stave is a target body).then and there click on mesh - introduce – contact estimating formerly go to points of interest of interaction measuring and choice contact location (liquid to stave) formerly choose significance is 100 and then choice mesh generate. It determination be take couple of moment used for mesh formation. The cross section of distinctive cases is indicated in Figure 12.

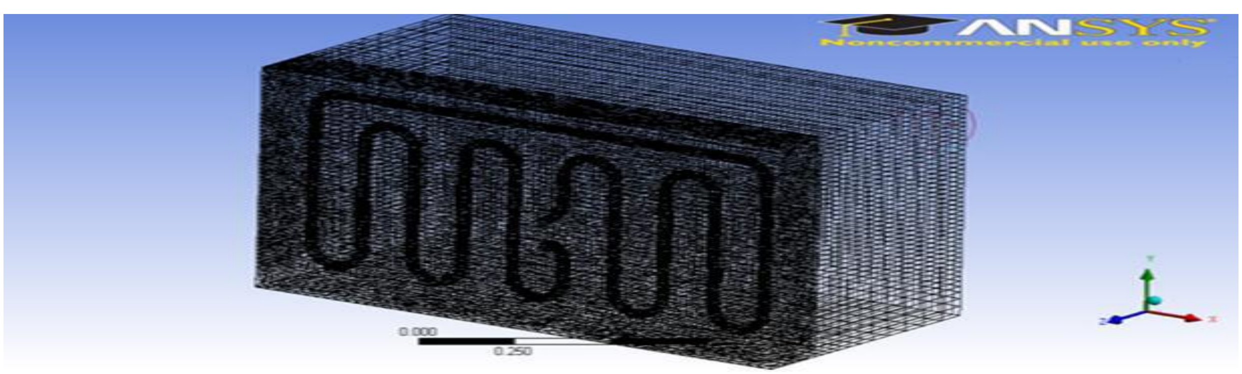


Figure 10 meshing of stave cooler with refractory lining

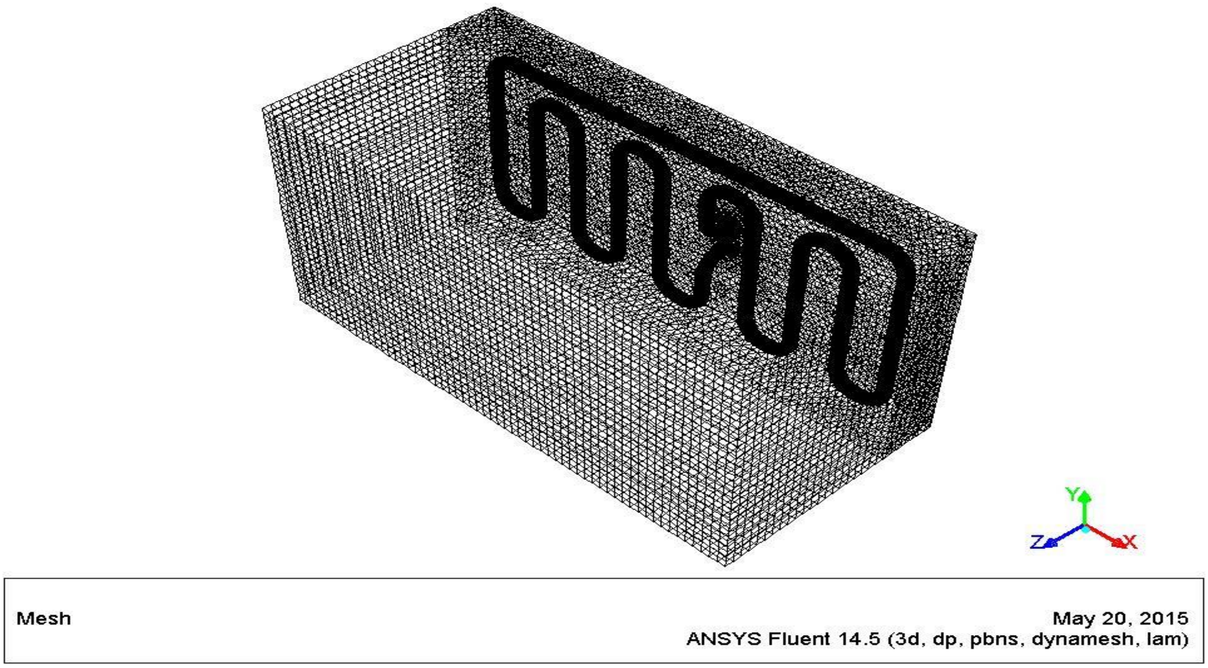


Figure 11 back side view of meshing of refractory lining with stave.

Fluent SETUP:-

Mesh document has been produced in workbench, which has imported into FLUENT for the investigation of stave with refractory lining.

- First click on general and then click on scale and then convert meter into millimeter.
- Now click on Models and click on energy and then choose the energy mathematical statement alright and then double click on thick choose k-epsilon (2 equations) then alright.
- Next goes to Materials folder and then to click on the liquid and where click on the fluent database-choose water as fluid then goes copy and then close and now to click the change/create after that close then click on fluent database and alteration the material sort

liquid to solid choose that material like (aluminum, copper, and so on)-duplicate close and change/make close.

- Click on Cell zone settings folder and where click on liquid alteration material name air to water fluid alright and then to click on section 2 is refractory material name-alright of course and click on section 2 is stave change the material name –alright.
- After that click the folder Mesh interface and then to click on make/alter choose interface strong/ fluid give name in mesh interface setting and choose coupled wall make then close.
- Taken as Boundary conditions setting that is rate of mass flow, heat flux, and inlet temperature of channel and outlet is 300K,
- Now going to Dynamic mesh choose the element cross on section smoothing.
- For the Reference quality chooses the heat confronts in figure shape and choose section 2 obstinate in reference zone.
- Now Solution strategy folders choose the turbulent dissipation rate and energy, turbulent kinetic energy, second request upwind in energy.
- Next is Monitors and click on lingering composing 1e-06 in all factors aside from energy alright.
- In the Solution introduction choose the mass flow rate in figure shape and then introduce.
- At last go on run computation and give the number of cycle and then compute.

3.2.2 *FLUID FLOW EQUATION*

1. Energy Equation:

$$\rho c_p\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)=\left(u\frac{\partial p}{\partial x}+v\frac{\partial p}{\partial y}+w\frac{\partial p}{\partial z}\right)+k\nabla^2T+\mu\phi$$

Where,

$$\phi=2\left[\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial v}{\partial y}\right)^2+\left(\frac{\partial w}{\partial z}\right)^2\right]+\left[\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)^2+\left(\frac{\partial v}{\partial z}+\frac{\partial w}{\partial y}\right)^2+\left(\frac{\partial w}{\partial x}+\frac{\partial u}{\partial z}\right)^2\right]$$

$$-\frac{2}{3}\left[\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}\right]^2$$

2. Navier-stokes equation

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=\rho x-\frac{\partial p}{\partial x}+\frac{1}{3}\mu\frac{\partial}{\partial x}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}\right)+\mu\nabla^2u$$

3. Continuity equation

$$\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0$$

For estimation of heat separated is utilized the Formula

Heat separated Q is calculated as

$$Q = m \times c_p \times (T_2 - T_1)$$

Where, T_1 = Inlet temperature

T_2 = outlet temperature

Cp = particular heat of water

m = Weight of the water

Fourier's law:

The Fourier’s law is utilized for furnace heat conduction to figure out heat and heat flux of material. The –ve symbol show of temperature diminishing alongside the bearing of expanding thickness or heat flow course. The temperature angle is constantly negative along +ve x-course and in this way of estimation of Q gets to be sure.

$$Q = -K \times A \times \frac{dT}{dx}$$

Where, dX = thickness

dT = temperature distinction

K = thermal conductivity

A = area of surface

Q = flow of heat

CHAPTER 4

1.4 RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The refractory lining with stave body by selecting the water is the cooling agents & it analyzed temperature difference of stave body created at inlet and outlet. In Figure 13 Numerical study of refractory lining shape with stave takes indicated. It demonstrates the variety of temperature over the thickness of 650mm refractory lining with stave material surface. The heat wall demonstrates the most elevated temperature of 1440 K. This is on the grounds that heat flux is specifically connected to surface. With expansion in separation in bearing far from heat wall and temperature slowly diminishes. Here stave material temperature is 397 K. coil of cooling liquid temperature is 300 K and outlet temperature is 307.8K, that demonstrates 7.8 K ascend in temperature. Fig 13 demonstrates the different cross-sectional perspective of stave body with refractory.

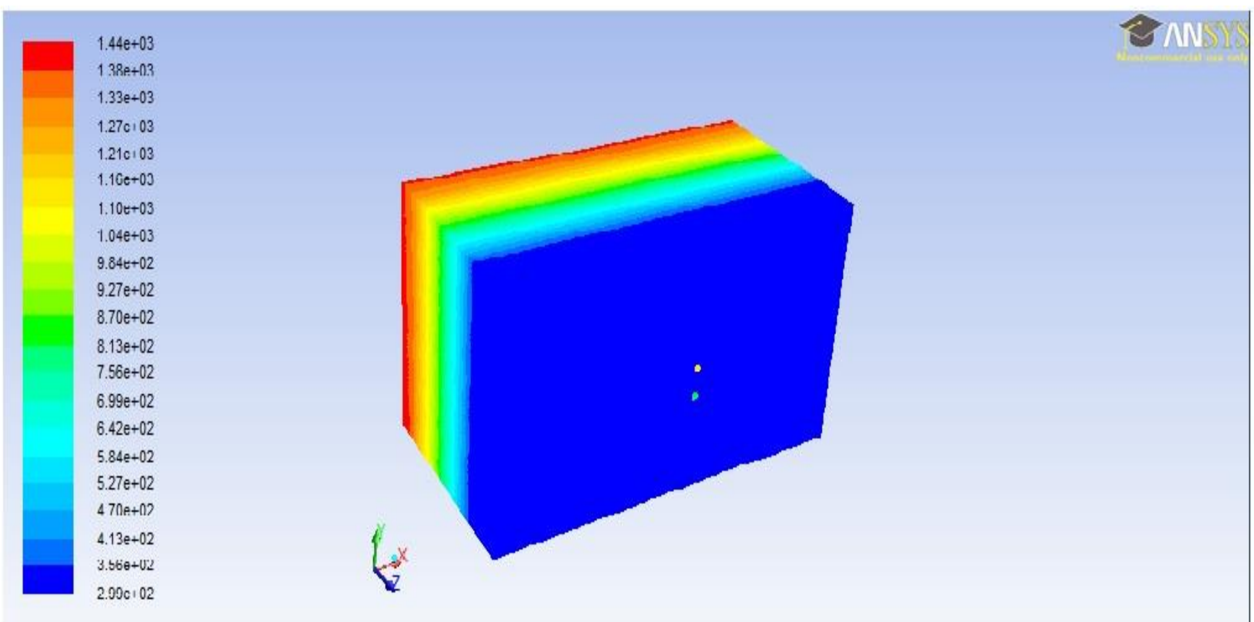


Figure 12 refractory lining (650mm) with stave 3D model

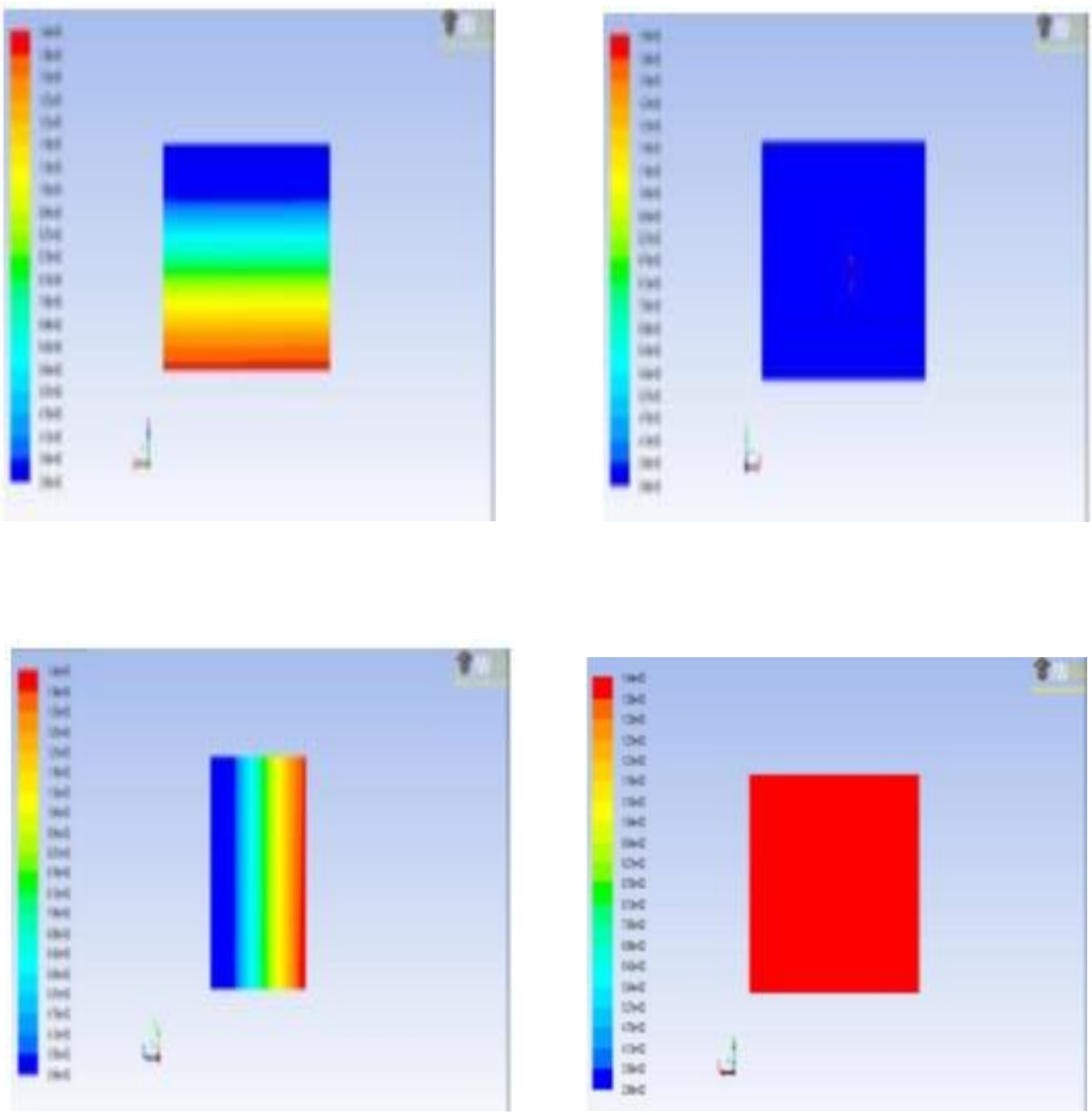


Figure 13 Rear, Front, Top view, Side view.

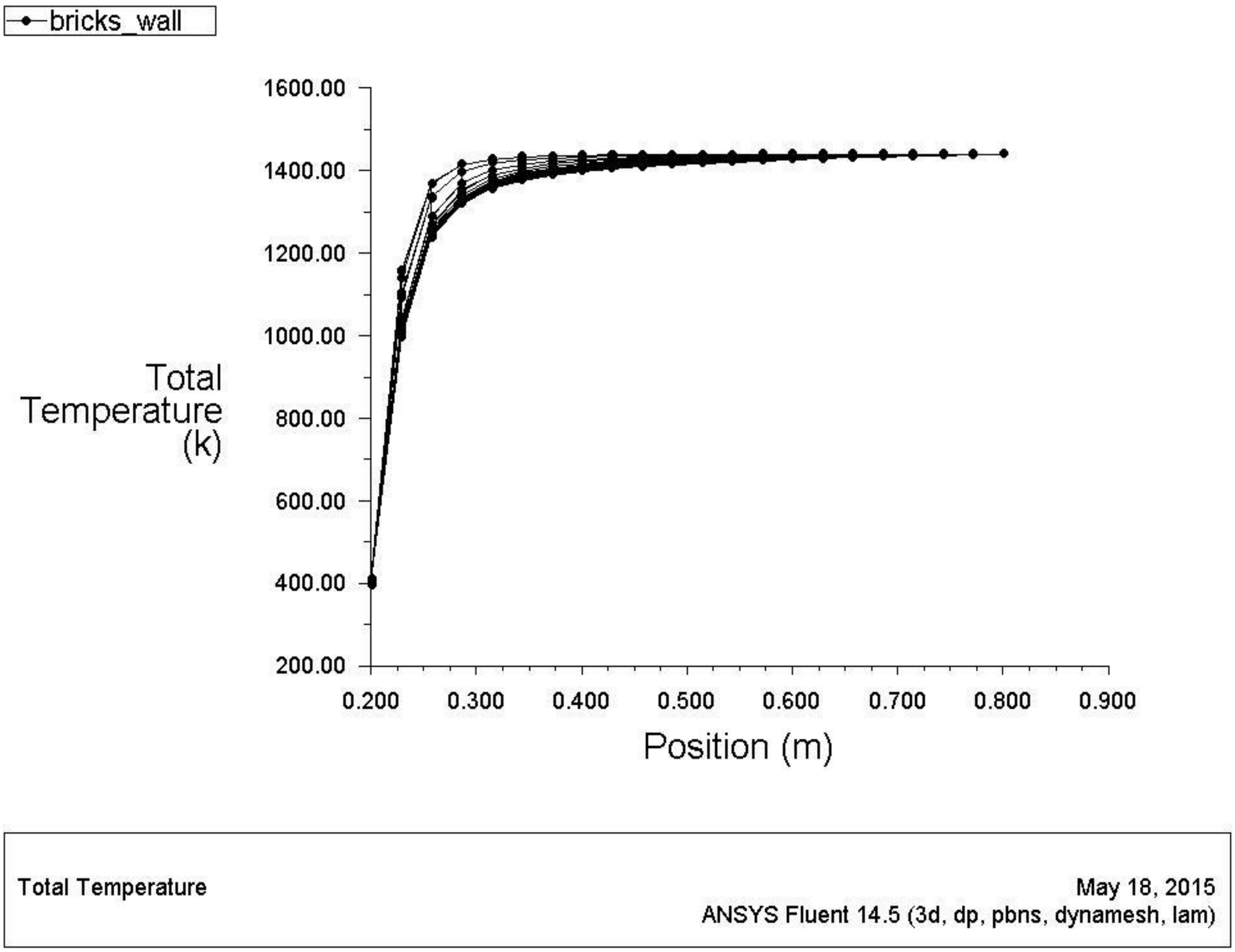


Figure 14 Total temperature (k) vs. distance (m) of bricks wall where mass flow rate is 2 kg/s.

In the figure 15 shows that the graph between total temperature and the distance of the bricks wall and mass flow rate is 2 kg/s. The graph is plotted on ansys fluent software. Here the temperature of the refractory lining is decreased with the instantaneous length of the refractory. Here the refractory temperature is 1440 k. After increasing the mass flow rate at 2 kg/s, the refractory temperature becomes 1320 k with refractory thickness 650 mm. Therefore the temperature difference is 120 k.

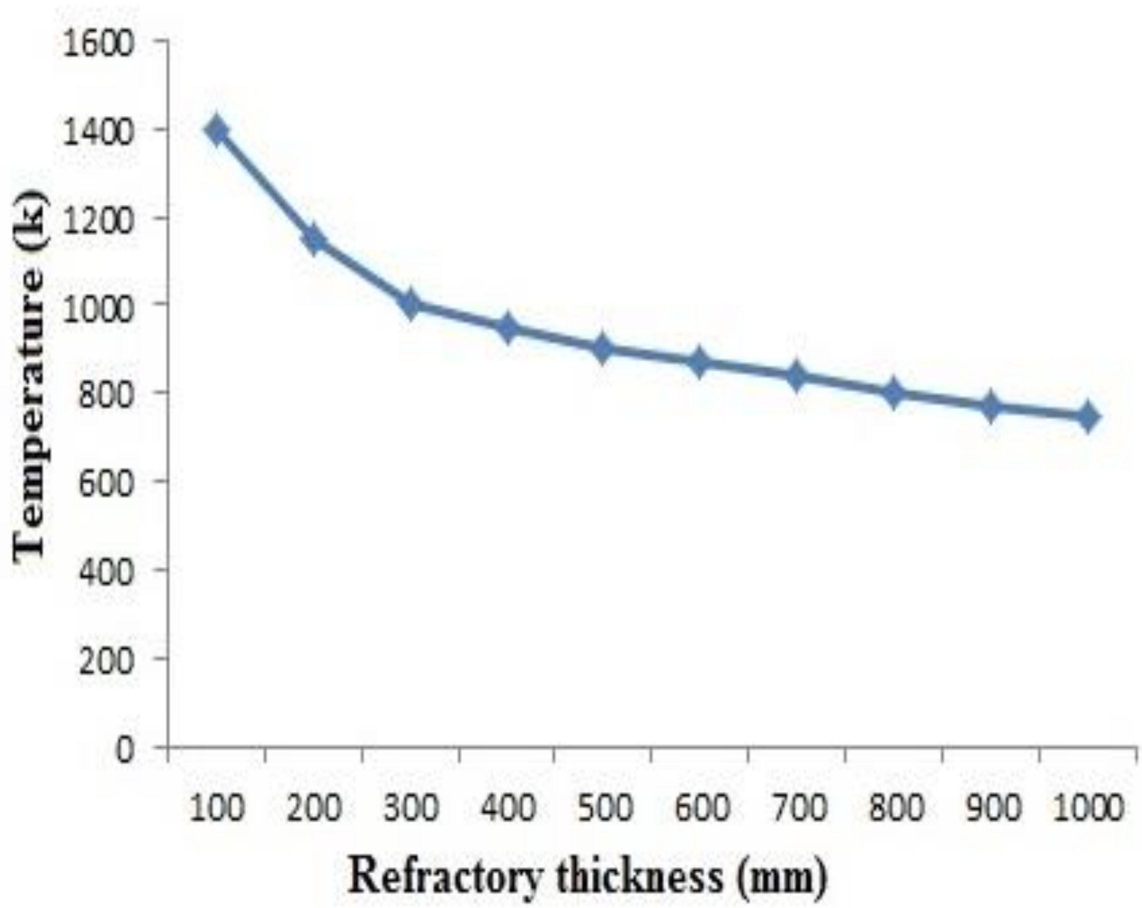


Figure 16. Temperature variation with refractory thickness where mass flow rate is 5 kg/s.

From figure 16, it shows that the temperature variation with refractory thickness where mass flow rate is 5 kg/s. Here the refractory temperature is 1440 k. In this the temperature decreases 950 k at refractory thickness of 650 mm. Therefore the difference of temperature is 490 k. Hence it concludes that when the mass flow rate of fluid is increases, the temperature of the refractory lining will be decreases.

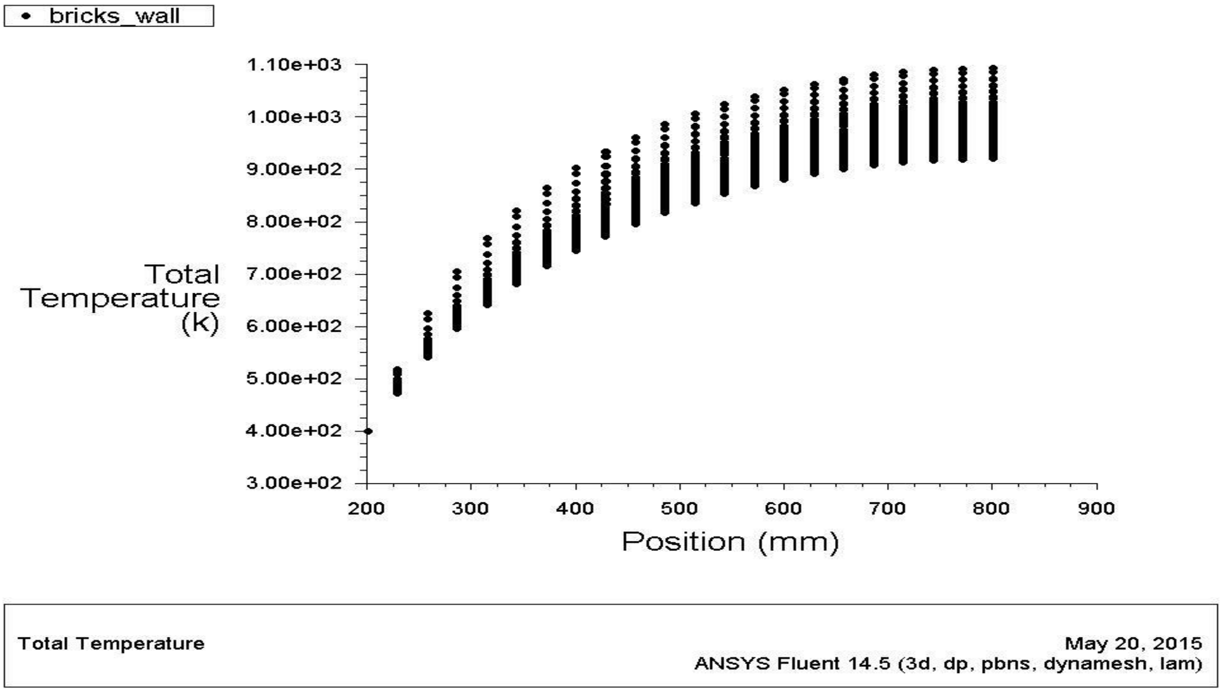


Figure17. bricks wall temperature versus position (mm)

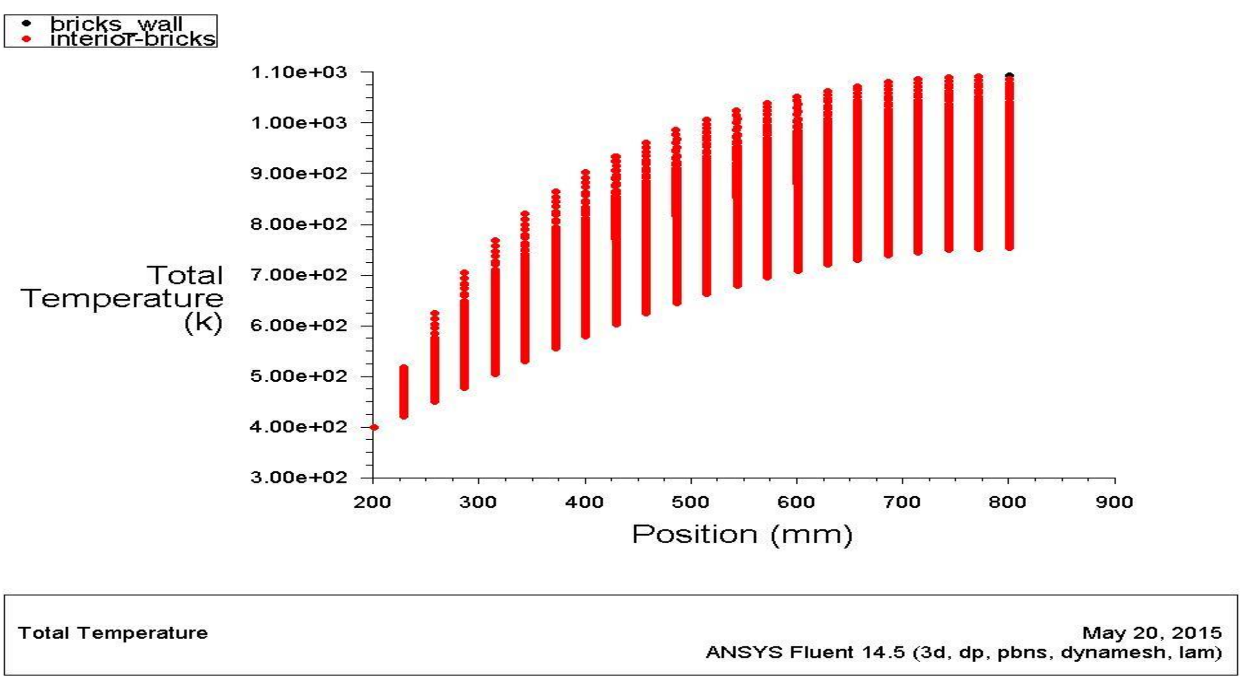


Figure18. bricks wall and interior bricks temperature versus position (mm)

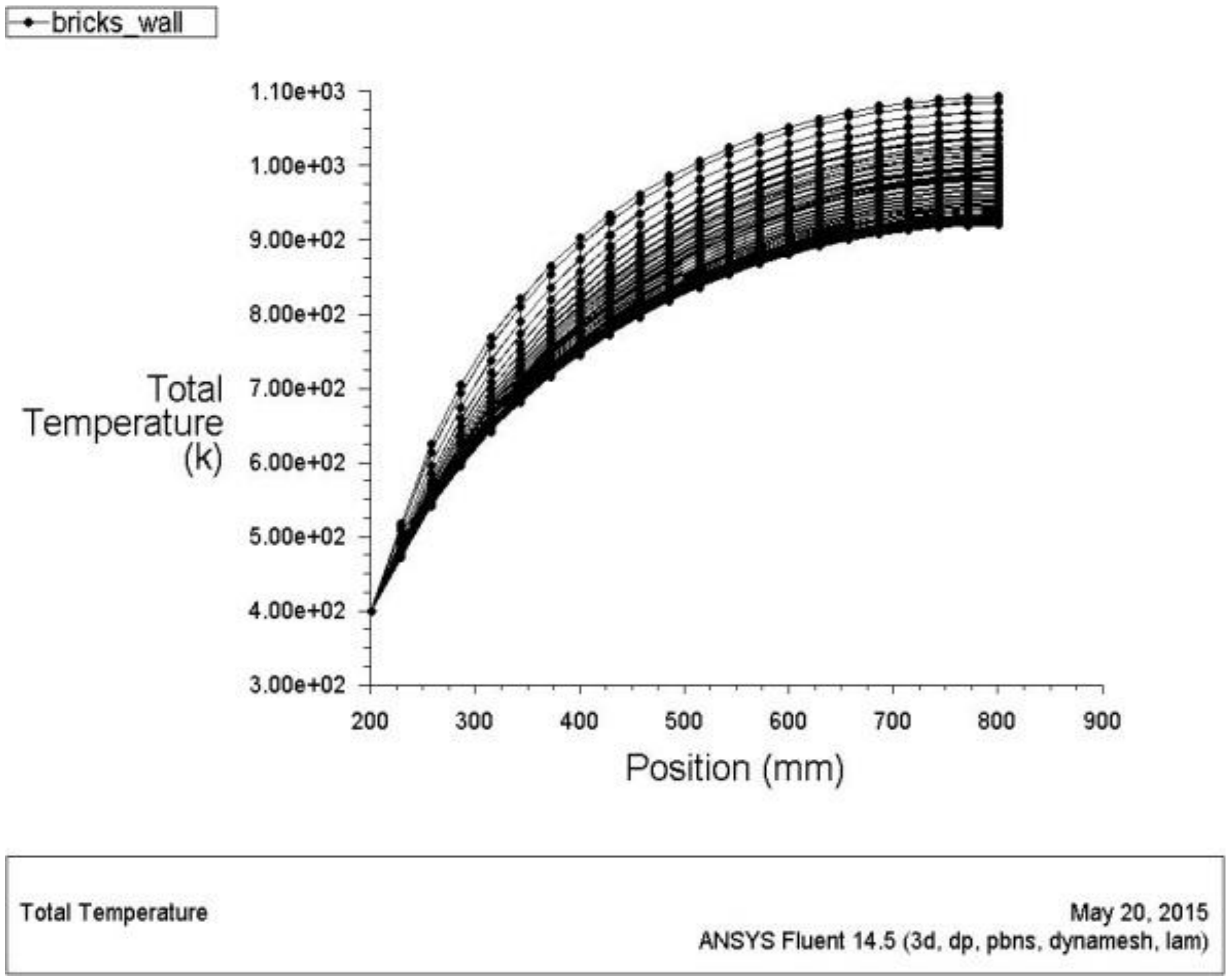


Figure19. bricks wall temp. versus position (mm)

In the figure17, figure 18, figure 19 shows that the bricks wall temperature versus position (mm). In this graph the total temperature of bricks becomes decrease through the position or distance of refractory with stave body of the furnace. Therefore the temperature decreases from 1100 k at the thickness of refractory 650 mm it shows in the figures.

Chapter 5

1.5 CONCLUSIONS

5. Conclusions

The conclusion of this work in refractory modeling and analysis by using ansys and fluent software. It is based on the boundary condition, assumption and different parameters. All these values are collected from RSP. Hence the got results it can be concluded that:

- When increasing the cooling rate of fluid, the thickness of refractory lining of blast furnace is decreases.
- The temperature variation with refractory lining for changing the mass flow rate.
- By decreasing the volume of refractory thickness, the production rate of blast furnace will be enhanced.

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